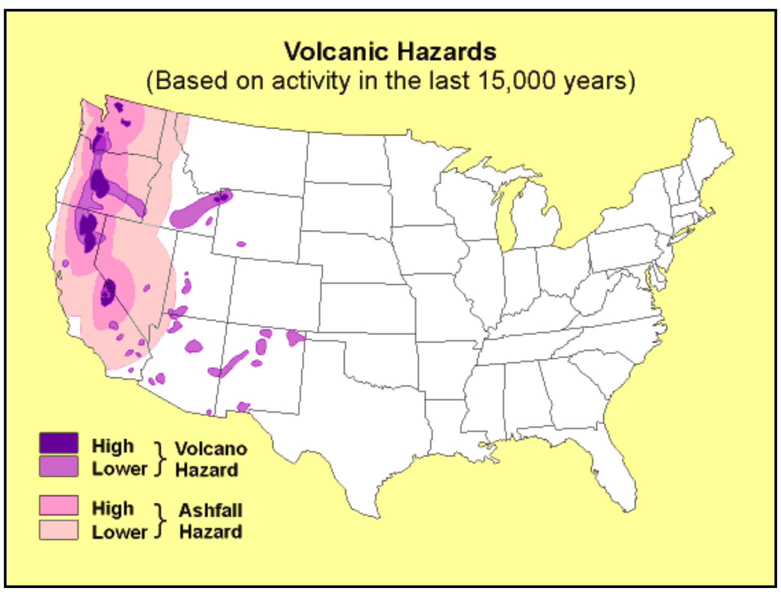
3.3.7 Volcanic Eruptions

Volcanic eruptions are generally not a major concern in Montana due to the relatively low probability (compared with other hazards) of events in any given year. However, Montana is within a region with a significant component of volcanic activity and has experienced the effects of volcanic activity as recently as 1980 (the eruption of Mount St. Helens in the state of Washington).

3.3.7.1 Background

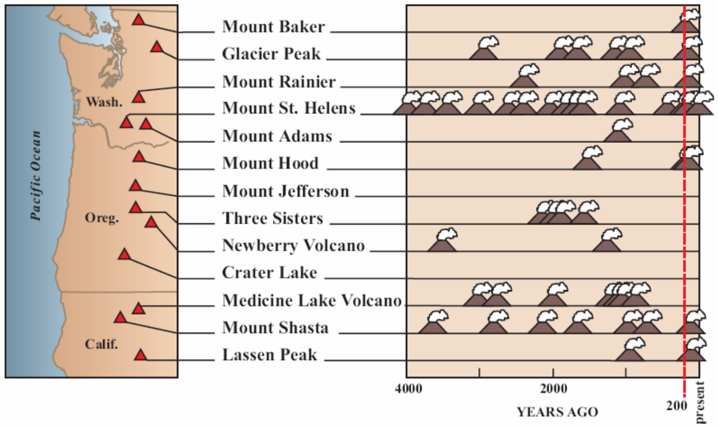
- There are 20 active or potentially-active volcanoes in the United States (**Figure 3.3.7-1**).
- The two volcanic centers affecting Montana in recent geologic time are: 1) the Cascade Range of Washington, Oregon and California; and 2) the Yellowstone Caldera in Wyoming and eastern Idaho.
- Volcanic eruptions in the Cascade Mountains are more likely to impact Montana than Yellowstone eruptions, based on the historic trends of past eruptions (**Figure 3.3.7-2**). The primary effect of the Cascade volcanic eruptions on Montana would be ashfall.
- The distribution of ash from a violent eruption is a function of the weather, particularly wind direction and speed and atmospheric stability, and the duration of the eruption. As the prevailing wind in the mid-latitudes of the northern hemisphere is generally from the west, ash is usually spread eastward from the volcano. Exceptions to this rule do, however, occur.
- Ashfall, because of its potential widespread distribution, offers some significant volcanic hazards.
-

Figure 3.3.7-1 Volcanic Hazards (based on activity in the last 15,000 years).



Areas in purple show regions at greater or lesser risk of volcanic activity, including lava flows, ashfall, lahar (volcanic mudflows) and debris avalanches, based on the record of the last 15,000 years, as compiled by Mullineaux (1976). Areas in pink show regions at risk of receiving 5 cm or more of ashfall from large or very large explosive eruptions originating at the volcanic centers shown in purple. These projected ashfall extents are based on observed ashfall distribution from a large eruption of Mt. St. Helens that took place 3,400 years ago, and the eruption of Mount Mazama that formed Crater Lake, Oregon, 6,800 years ago.

Figure 3.3.7-2 Cascade Eruptions during the Past 4,000 Years
Source: USGS, 2007



3.3.7.2 History of Volcanic Eruptions Affecting Montana

Table 3.3.7-1 shows the thicknesses of recorded ash deposits within Montana. The most recent ash was deposited in May 1980 after the Mount St. Helens eruption in the state of Washington. **Figure 3.3.7-3** shows the distribution of ash from some of these events. The trajectory of ashfall events is heavily dependent upon the size of the eruption and the prevailing weather and ambient winds.

Table 3.3.7-1 Recent Volcanic Ash Events Affecting Montana

Volcano	Most Recent Eruption (Yrs before Present)	Location Affected	Thickness of Ash in Montana
Yellowstone Caldera	665,000	Eastern Montana	
Glacier Peak	14,500	Western Montana	1.2 inches (compacted)
Crater Lake (Mt. Mazama)	7,600	Western Montana	Up to 6 inches (compacted)
Mount St. Helens	23	Entire State	Up to 0.2 inches (uncompacted)

Source: MDES, 1996; Sarna-Wojcicki and others, 1981; USGS, 2003a; Nimlos, 1981.

Cascade Eruptions

The Cascade Range includes 27 volcanoes, many of which have been active in the last 4,000 years (**Figure 3.3.7-2**). The major threat these volcanoes pose to Montana is ashfall. The likely extent of such ashfall can be estimated on the basis of past eruptions.

After the eruption of Mount St. Helens in May 1980, a coating of up to 5.0 mm (0.2 inches) of ash fell on Western Montana (Sarna-Wojcicki and others, 1981). Ash deposits were thickest in the western portions of the state, tapering to near zero on the eastern part of the state (**Figure 3.3.7-3**). It is estimated that the ashfall cost Missoula County nearly $6 million in cleanup and lost work time. The statewide cost has been estimated at between $15 and $20 million (MDES, 2004).

Travel was restricted in Western Montana for over a week because of concerns for public health, but the ash was determined to be a physical respiratory irritant, but not a toxic substance. The main hazards in Western Montana included reduced visibility (and resulting closed roads and airports), clogging of air filters, and a health risk to children, the elderly, and people with cardiac or respiratory conditions, such as asthma, chronic bronchitis, and emphysema. Claims for State facilities totaled approximately $55,000 (MDES, 2004).

Figure 3.3.7-3 Areas of the U.S. Once Covered by Volcanic Ash

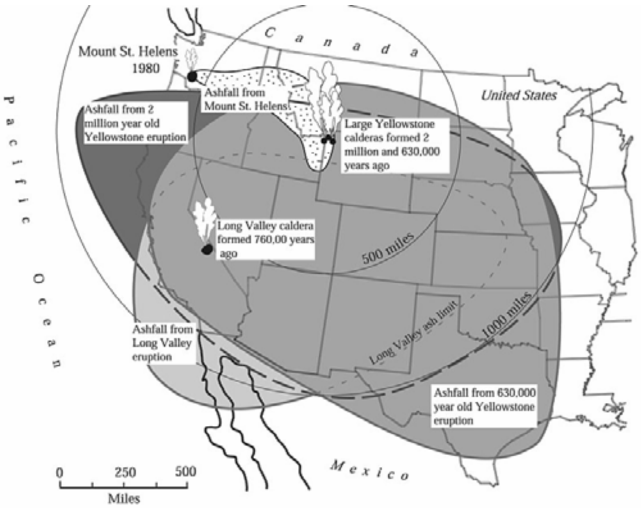
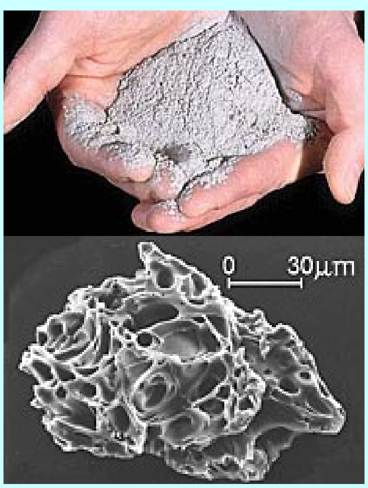


Figure 3.3.7-3 shows distribution of ashfall from Yellowstone's giant eruptions 2 million and 630,000 years ago, compared with ashfall from the 760,000-year-old Long Valley caldera eruptions at Mammoth Lakes, California, and the 1980 eruption of Mount St. Helens, Washington (Adapted from Sarna-Wojcicki, 1991).

The 1980 Mount St. Helens eruption was not a large eruption by world historical standards or even among prior Cascade eruptions. The amount of volcanic material ejected into the air from Mount St. Helens in 1980 (less than one-tenth cubic mile) was only about 1/80th of the volume ejected during the 1815 eruption of the Tambora volcano in Indonesia and less than 1/100th of the estimated ejecta from Mount Mazama during the eruption that formed Crater Lake. Therefore, future eruptions of large Cascade volcanoes, including Mount St. Helens, might be much larger than the May 18, 1980 eruption (Foxworthy and Hill, 1982). **Table 3.3.7-3** describes the effects of volcanic ash.

Table 3.3.7-2 Effects of Volcanic Ash

 Volcanic ash, like this 1980 ash from Mount St. Helens, is made up of tiny jagged particles of rock and glass (photo on bottom; magnified 200 times).	▪ Short-circuits and failure of electronic components, especially high-voltage circuits and transformers (wet ash conducts electricity). ▪ Eruption clouds and ashfall commonly interrupt or prevent telephone and radio communications. ▪ Volcanic ash can cause internal-combustion engines to stall by clogging air filters and also damage the moving parts. Engines of jet aircraft have suddenly failed after flying through clouds of even thinly dispersed ash. ▪ Roads, highways, and airport runways can be made treacherous or impassable because ash is slippery and may reduce visibility to near zero. Cars driving faster than 5 miles per hour on ash-covered roads stir up thick clouds of ash, reducing visibility and causing accidents. ▪ Ash also clogs filters used in air-ventilation systems to the point that airflow often stops completely, causing equipment to overheat. ▪ Crop damage can range from negligible to severe, depending on the thickness of ash, type and maturity of plants, and timing of subsequent rainfall. ▪ Like airborne particles from dust storms, forest fires, and air pollution, volcanic ash poses a health risk, especially to children, the elderly, and people with cardiac or respiratory conditions, such as asthma, chronic bronchitis, and emphysema.

Source: USGS, 2003b

Yellowstone Eruptions

Another area of volcanic activity that has affected Montana in the past and could pose a serious threat in the future is the Yellowstone Caldera in northwestern Wyoming, just south of the Montana border. A caldera is a term for a large volcanic crater. The Yellowstone Caldera is 45 miles across at its greatest diameter. The spectacular geysers, boiling hot springs, and mud pots that have made Yellowstone famous are surface manifestations of a magma chamber at depth.

Cataclysmic eruptions 2.0, 1.3, and 0.6 million years ago ejected huge volumes of rhyolite magma; each eruption formed a caldera and extensive layers of thick pyroclastic-flow deposits. The caldera is buried by several extensive rhyolite lava flows that erupted between 75,000 and 150,000 years ago. Fortunately for mankind, an eruption comparable in magnitude with those of Yellowstone has not occurred during recorded history. Initial lava flows were confined to the immediate area of the vent, but later flows inundated the headwaters of the Yellowstone River, near Gardiner. Pyroclastic flows (the Huckleberry Ridge Tuff) extended up to 55 miles from the vents.

3.3.7.3 Declared Disasters from Volcanic Eruptions

The 1980 Mount St. Helens eruption covered most of the state with variable amounts of ash. Based on MDES records, Lake County was the only Montana County to apply for state assistance (**Table 3.3.7-3**).

Table 3.3.7-3 State Declarations for Volcanic Hazards

Date	Pa. No.	Applicant	State	Local	Comments
1980	ST-80-1	Lake County	$ 8,320	$47,102	Volcanic Ash Fallout (Mt. St. Helens) & Flooding

3.3.7.4 Vulnerability to Volcanic Eruptions

3.3.7.4.1 Statewide Vulnerability to Volcanic Eruptions

The US Geological Survey has determined that two areas in Montana may have exposure to volcanic hazards:

1. The extreme western edge of Montana (Lincoln, Sanders, and Mineral Counties) could be subject to ashfall of 5 mm or greater from eruptions of the Cascade Volcanoes.
2. The southwestern corner of the state (portions of Madison and Gallatin Counties) could be subject to ash flows, lava flows, and lahars (ash/mudflows) from a Yellowstone eruption.

The primary hazard to which the State may be vulnerable at some future time, is ashfall from a Cascade volcano. Eruptions in the Cascades have occurred at an average rate of 1-2 per century during the last 4,000 years, and future eruptions are certain. Seven volcanoes in the Cascades have erupted in the last 200 years. The next eruption in the Cascades could affect hundreds of thousands of people. The effect in Montana would depend on the interaction of such variables as source location, frequency, magnitude and duration of eruptions, the nature of the ejected material and the weather conditions. Therefore, the entire state may be considered vulnerable to ashfall to some degree in the event of a volcanic eruption.

The USGS assessment reflects a “recent” record of volcanic activity within the last 15,000 years. There is evidence that ashfall from a Yellowstone eruption could impact a far greater area and have significant impact on the southern half of Montana. Three major periods of activity in the Yellowstone system have occurred at intervals of approximately 600,000 years, and the most recent was about 600,000 years ago. The evidence available is not sufficient to confirm that calderas such as the one in Yellowstone erupt at regular intervals, so the amount of time elapsed is not necessarily a valid indicator of imminent activity. There is no doubt, however, that a large body of molten magma exists, probably less than a mile beneath the surface of Yellowstone National Park. The presence of this body has been detected by scientists who discovered that earthquake waves passing beneath the park behave as if passing through a liquid. The only liquid at that location that could absorb those waves is molten rock. The extremely high temperatures of some of the hot springs in the park further suggest the existence of molten rock at shallow depth. A small upward movement in the magma could easily cause this magma to erupt at the surface. If a major eruption occurred, the explosion would be "comparable to what we might expect if a major nuclear arsenal were to explode all at once, in one place" (Alt and Hyndman, 1986).

Although the probability is minimal, there is the potential for a catastrophic eruption in the vicinity of Yellowstone National Park that would have very serious consequences for Montana and neighboring states. Again, assessing the vulnerability of the State to such an event is impossible due to the numerous variables and uncertainties that must be considered.

3.3.7.4.2 Review of Potential Losses in Local PDM Plans

Figure 3.3.7-4 presents the Volcanic Eruption Hazard Risk Map. The colors represent a high-medium-low risk rating based on information in the Local PDM Plans. The gray color indicates this hazard was not assessed in the Local Plan. The hatch pattern indicates the Local Plans were not available for review. For electronic users of the State Plan, clicking on a county or tribal reservation will take you to the Local Plan where further information is available.

Table 3.3.7-4 presents a summary of potential loss estimates due to volcanic eruption as calculated in the Local PDM Plans. Volcanic eruption loss is described in terms of its effect on buildings, society and the economy, where generally:

- Building loss is presented either as a dollar value or a high-moderate-low rating and typically refers to the potential loss to critical facilities in the jurisdiction.
- Societal loss is presented either as the number of lives at risk or as a high-moderate-low rating representing the potential for loss of human life.
- Economic risk is presented as a dollar value or high-moderate-low rating referring to the potential impact to the economy of the local jurisdiction.

References cited in **Table 3.3.7-4** correspond to a description of the method used to calculate potential loss that can be found in *Section 7.14.*

Figure 3.3.7-4 Hazard Risk Map: Volcanic Eruption

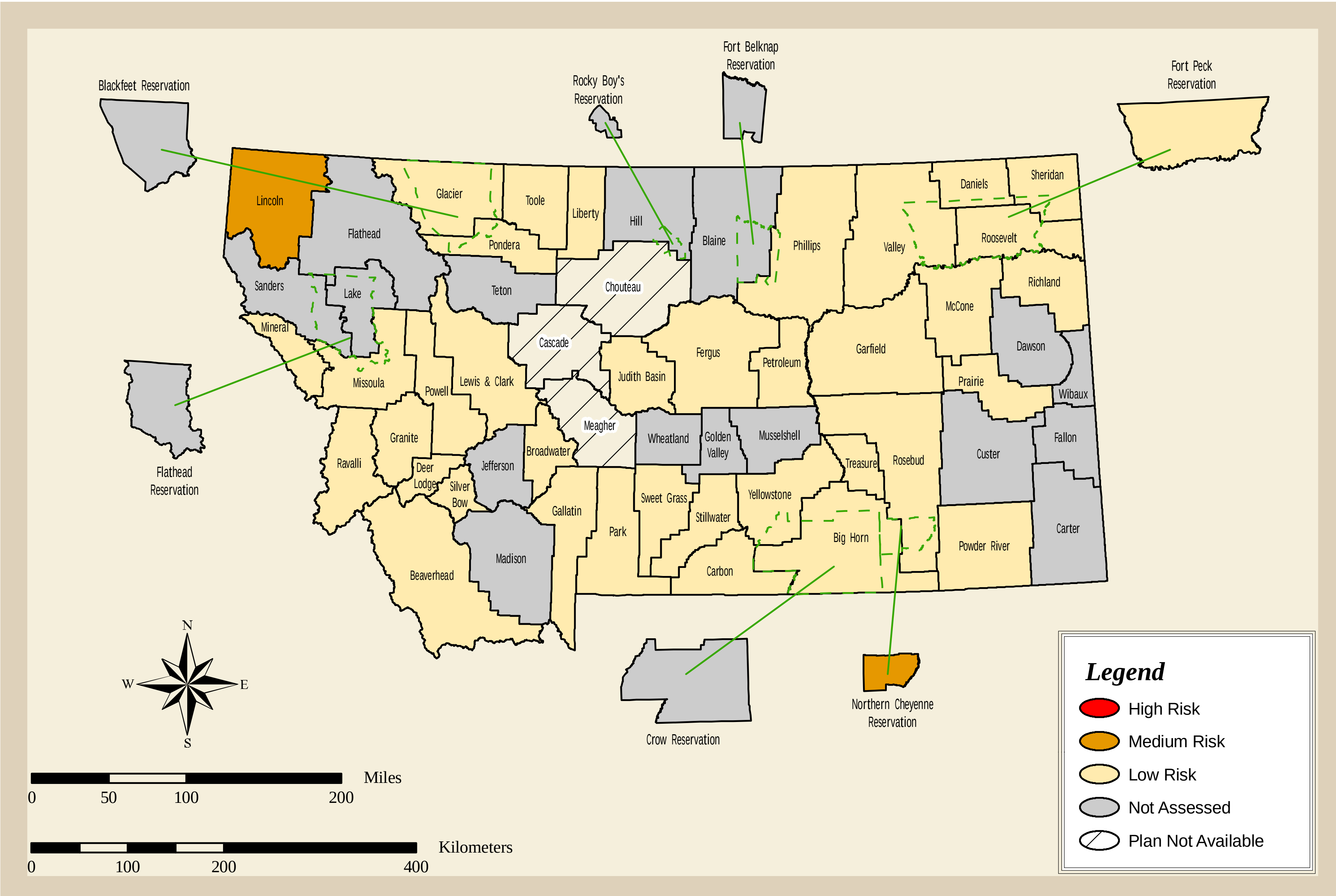


Table 3.3.7-4 Potential Losses from Local Plans: Volcanic Eruption

DES District	Jurisdiction	Building Loss	Societal Loss	Economic Loss	Reference
1	Deer Lodge County	Moderate	Moderate	Low	1
1	Flathead County	NA	NA	NA	
1	Flathead Reservation	NA	NA	NA	
1	Granite County	NA	NA	NA	
1	Lake County	NA	NA	NA	
1	Lincoln County	NA	NA	NA	
1	Mineral County	$200,00-$500,000	Low	NA	10
1	Missoula County	$1-$2 million	Low	NA	10
1	Powell County	Low	Low	NA	10
1	Ravalli County	$1 million	Low	NA	10
1	Sanders County	NA	NA	NA	
1	Silver Bow County	Low	Low	Low	1
2	Blackfeet Reservation	NA	NA	NA	
2	Blaine County	NA	NA	NA	
2	Cascade County	U	U	U	
2	Chouteau County	U	U	U	
2	Fort Belknap Reservation	NA	NA	NA	
2	Glacier County	NA	NA	NA	
2	Hill County	NA	NA	NA	
2	Liberty County	Low	Low	Low	11
2	Pondera County	NA	NA	NA	
2	Rocky Boy's Reservation	NA	NA	NA	
2	Teton County	NA	NA	NA	
2	Toole County	High	High	NA	11
3	Beaverhead County	NA	NA	NA	
3	Broadwater County	Moderate	Low	Low	1
3	Gallatin County	Moderate	Moderate	Moderate	12
3	Jefferson County	NA	NA	NA	
3	Lewis & Clark County	NA	NA	NA	
3	Madison County	NA	NA	NA	
3	Meagher County	U	U	U	
3	Park County	Moderate	Moderate	Moderate	1
3	Sweet Grass County	NA	NA	NA	
4	Carter County	NA	NA	NA	
4	Custer County	NA	NA	NA	
4	Dawson County	NA	NA	NA	
4	Fallon County	NA	NA	NA	
4	Garfield County	Low-Moderate	Low	Low-Moderate	1
4	McCone County	Low	Low	Moderate	3
4	Powder River County	Low	Low	Low	1
4	Prairie County	Millions	NA	NA	3
4	Richland County	Millions	NA	NA	3
4	Wibaux County	NA	NA	NA	
5	Big Horn County	$6,000,000	NA	Severe	3
5	Carbon County	NA	NA	NA	

Table 3.3.7-4 Potential Losses from Local Plans: Volcanic Eruption

DES District	Jurisdiction	Building Loss	Societal Loss	Economic Loss	Reference
5	Crow Reservation	$6,000,000	Moderate-High	Moderate-High	3
5	Golden Valley County	NA	NA	NA	
5	Musselshell County	NA	NA	NA	
5	Northern Cheyenne Reservation	NA	NA	$6 million	3
5	Rosebud County	Moderate	Low	Moderate	1
5	Stillwater County	NA	NA	NA	
5	Treasure County	Moderate	Low	Moderate	1
5	Wheatland County	NA	NA	NA	
5	Yellowstone County	NA	NA	NA	
6	Daniels County	NA	NA	NA	
6	Fergus County	NA	2	4	4
6	Fort Peck Reservation	NA	NA	NA	
6	Judith Basin County	NA	NA	NA	
6	Petroleum County	NA	NA	NA	
6	Phillips County	NA	NA	NA	
6	Roosevelt County	NA	NA	NA	
6	Sheridan County	NA	NA	NA	
6	Valley County	NA	NA	NA	

Notes: U = Local PDM Plan not available for review; NA = not assessed in Local PDM Plan
Potential loss was computed was not computed in a uniform manner in Local PDM Plans. See number references in *Section 7.14* for a description of the methods used to calculate potential building, society and economic loss.

3.3.7.4.3 Vulnerability of State Property

Exposure to State-owned facilities can be classified into two types of events: a Yellowstone eruption causing ash flows and tefra fallout impacting the immediate area, and ashfalls from either a Yellowstone eruption or a Cascade Volcano eruption blanketing portions of the state. The most likely event would be a Cascade volcano eruption causing ashfall in the western portion of the state. An ashfall event could cause equipment failure to the State's motor-pool and other motorized equipment. Clearing the ashfall from the State's highways would cause extra resources devoted to the clean up. The overall impact to the State-owned facilities would be minor.

A Yellowstone eruption could be devastating. While the immediate area would have the greatest exposure to ash flows, tefra fallout, and mudflows, heavy ashfall could have severe impacts on areas within 100 miles of the eruption. The counties with greatest vulnerability are those that are located within 100 miles of Yellowstone Park. Those counties and the value of State-owned facilities are shown in **Table 3.3.7-5**.

Table 3.3.7-5 State Building Values in Counties Highly Vulnerable to Yellowstone Eruption

County	Building Value	Contents Value	Total Value	State Employee Count
Gallatin	$628,106,416	$313,624,692	$941,731,108	407
Madison	$12,293,758	$562,960	$12,856,718	63
Broadwater	$13,193,938	$9,366,472	$22,560,410	130
Park	$3,102,043	$935,509	$4,037,552	79
Jefferson	$23,951,910	$5,890,780	$29,842,690	759
Carbon	$1,149,030	$446,856	$1,595,886	56
Stillwater	$497,276	$138,322	$635,598	36
TOTALS	**$682,294,371**	**$330,965,591**	**$1,013,259,962**	**1,530**

Source: DOA, Risk Management and Tort Defense Division, 2007

3.3.7.5 Impact of Future Development

As population increases in the west and southwest Montana and recreational usage is expanding, more and more people and property are at risk from ashfall associated with volcanic activity.

3.3.7.6 Volcanic Eruptions Data Limitations

To effectively determine the vulnerability of State property, data identifying locations of State buildings is necessary. The current Montana Department of Administration (DOA), Risk Management and Tort Defense PCIIS building database is not geo-referenced and cannot be effectively related to spatial coordinates except in general locations (by city or zipcode centroid). Volcanic eruptions are somewhat unpredictable events, and the ashfall is highly dependent on weather parameters. Generally, Western and Southwestern Montana is considered more vulnerable than other parts of state given their proximity to volcanic areas, however, the data limitations of weather and the science of volcanoes and related effects do not allow for more specific analysis.

3.3.7.7 Volcanic Eruption References

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